Venus Global Reference Atmospheric Model (Venus-GRAM)

Introduction

Marshall Space Flight Center's Natural Environments Branch has developed Global Reference Atmospheric Models (GRAMs) for Mars, Venus, Earth, and other solar system destinations. Venus-GRAM is based on the Committee on Space Research (COSPAR) Venus International Reference Atmosphere (VIRA), and is suitable for a variety of engineering applications at all attitudes, locations, and times within the atmosphere of Venus.

Data Sources For Venus-GRAM

Dependence of Venus-GRAM mean atmospheric parameters on height, latitude, and time-of-day (or solar zenith angle) is based on A.J. Kliore, V. I. Moroz, and G. M. Keating (editors), "The Venus International Reference Atmosphere", Advances in Space Research, vol. 5, no. 11, 1985, pages 1-304 (1986), Pergamon Press, Oxford.

Other data sources include D.M. Hunten, L. Colin, T.M. Donahue, and V.I. Moroz (editors), "Venus", University of Arizona Press, Tucson, (1983), S.W. Bougher, D.M. Hunten, and R.J. Phillips (editors), "Venus II", University of Arizona Press, Tucson (1997), referred to here as "Venus II", and M.Y. Marov, and D.H. Grinspoon (editors), "The Planet Venus", Yale University Press, New Haven (1998) .

Variation of "mean" thermodynamic parameters with altitude is from VIRA data. For heights up to 100 km, this is VIRA data for latitudes < 30 degrees. For heights between 100 and 150 km, mean values are from an average of VIRA daytime (LST=12 hr) and nighttime (LST=0 hr) data. For heights between 150 and 250 km, mean values are from VIRA data for solar zenith angle 90 degrees.

Mean zonal wind (u) versus height up to 80 km is from approximations to VIRA data, the "VIRA model", and from Fig. 5, page 469 of "Venus II", with latitude variation from Fig. 8, page 696 of "Venus". Mean meridional wind (v) versus height up to 80 km and versus latitude is from Fig. 3, page 466 of "Venus II". Decrease in u above 80 km is parameterized from page 333 of Lellouch et al., Icarus 110, 315-319 (1994) and Fig 2. of Hou and Farrell, J. Atmos. Sci. 44, 1049-1061 (1987). At higher altitudes sub-solar to anti-solar diurnal wind is parameterized from Fig. 2 of Zhang et al. J. Geophys. Res. 101(E10), 23, 195-205 (1996) and Fig 4. of Bougher et al. Icarus, 73, 545-573 (1988). Note: Many references adopt the convention for Venus that super-rotating (westward, or retrograde) zonal winds are positive. We retain the traditional right-handed coordinate convention, whereby zonal winds are positive eastward and meridional winds are positive northward.

Up to 80 km, magnitudes of zonal and meridional wind perturbations are from approximations to VIRA data and the "VIRA Model". Above 80 km wind perturbation magnitudes are assumed to increase proportionally with increase in mean wind, from Fig. 2 of Zhang et al. J. Geophys. Res. 101(E10), 23, 195-205 (1996).

Magnitudes of density perturbations are estimated from temperature variations observed by Pioneer probes, taken from Figs. 1-8(d) and 1-12(a) of Seiff et al. VIRA data, pages 247, 259, and 278 of "Venus", pages 200 and 201 of "The Planet Venus", observed by Pioneer orbiter, taken from page 283 of "Venus II", and observed by Magellan radio occultation, take from Fig. 6 of Hinson and Jenkins Icarus 114, 310-327 (1995).

Horizontal scales of density perturbations were selected to be fairly consistent with wavelength estimates from Fig. 6 of Bougher and Borucki, J. Geophys. Res. 99(E2), 3759-3776 (1994), Fig. 2 of Mayr et al., J. Geophys. Res. 93(A10), 11247-262 (1988), Kasprzak et al. J. Geophys. Res. 93(A10), 11237-246 (1988), and Kasprzak et al. Geophys. Res. Lett. 20 2755-2758 (1993).